

## DESCRIPTION

## HOMOGENEOUS SEPARATOR

Technical Field

This invention relates to a separator for an alkaline battery and more particularly to a cellulose separator in a secondary zinc alkaline battery.

Background of the Invention

Separators play a crucial role in alkaline batteries. They keep the positive and negative sides of the battery separate while letting certain ions go through and blocking others. The separator is a passive element that has to perform the same task unchanged for the life of the battery. Additionally, the separator must be able to withstand a strongly alkaline environment at ambient and elevated temperatures and be able to resist oxidative attacks.

To meet the high current demands of modern electronics, there is an increasing need for an alkaline battery that contains a separator that can conduct hydroxyl ions at an increasingly rapid rate. Films of cellulose in the form of regenerated cellulose have been used since World War II as the separator of choice for this purpose because of its superior ability to conduct hydroxyl ion in strongly alkaline media. Its low electrical resistance of 10 milliohm-in<sup>2</sup> has also led to its desirability among manufacturers of zinc-based type batteries. These types of batteries include, among others, silver-zinc, zinc-nickel, and zinc manganese dioxide based batteries. Additionally, the cellulose acts as a physical barrier to migration of

other ions into the battery, particularly, zincate ions and silver ions in a silver-zinc battery.

In the presence of a silver cathode, regenerated cellulose performs a sacrificial role as all of the active  
5 centers are oxidized in the presence of silver ions with the simultaneous deposition of silver metal. This can have a deleterious effect on the water transport as well as the ionic conductivity of the membrane.

Limited developments have occurred in the improvement  
10 of regenerated cellulose as a battery separator. Regenerated cellulose films are the result of extensive processing of cellulose and involve a xanthation reaction thereof. Cellophane, manufactured by regeneration from cellulose, has a degree of polymerization between 350 and  
15 500. However, the regenerated cellulose separators presently used in zinc alkaline batteries do not have sufficient mechanical strength to withstand penetration by zinc dendrites and are subject to oxidation.

#### 20 Statement of the Prior Art

There have been different attempts to treat the surface of regenerated cellulose chemically. In U.S. Patent No. 5,763,557 Sanduja et al graft a polymer on to the surface of a film of cellophane by contacting the film  
25 with a solution of silver nitrate and an alkali-metal hydroxide and then contacting the film with a polymerizable monomer and a catalyst. The polymerization takes place directly on the surface molecules of the substrate. Similar techniques are used in U.S. Patent No. 5,342,659.  
30 There is no evidence, however, that surface treatment of regenerated cellulose significantly affects the ionic

conductivity of a separator formed from the surface treated material.

Crosslinking tends to increase dimensional stability and tensile strength. Various techniques are known to crosslink cellulose, either intramolecularly, intermolecularly, or both. Indeed it is known that crosslinking affects the mechanical properties of cellulose fibers. U.S. Patent No. 6,068,619 discloses the use of crosslinked cellulose fibers using 5% of dimethyloldihydroxyethyleneurea as the crosslinking agent with 5% of a metal salt catalyst as a method to improve the elasticity of fibers in the wet state. It is noted that crosslinked cellulose fibers by themselves absorb less liquid than uncrosslinked fibers.

Polyvinyl alcohol is a polymer that, when crosslinked, has been used as a battery separator. Polyvinyl alcohol is a substance containing two hydroxyl units per repeating unit. Sugiura et al in U.S. Patent No. 6,033,806 propose its use as a battery separator in a method entailing cleaving diol units using an oxidative agent and then crosslinking the diols using an acetalization reaction. This is necessary in order to render the normally water-soluble polymer into a water-insoluble polymer. Crosslinked polyvinyl alcohol, however, tends to have a higher electrical impedance than cellophane.

#### Statement of the Invention

The present invention provides mechanically strong separators that are resistant to silver oxidation. This has been achieved by dissolving cellulose and crosslinking it in a manner as to preserve the excellent ionic conductivity. A battery separator is provided whereby a

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cellulose solution containing cellulose having a degree of polymerization between 200 and 1200 is crosslinked with a hydrocarbon group containing 4 and 16 carbon atoms and said cellulose solution is coagulated to produce a gel that upon  
5 dehydration yields a film operable as a battery separator. This separator has higher mechanical strength than uncrosslinked separators.

#### Detailed Description of the Invention

10 The present invention discloses a battery separator that improves on the native strength of regenerated cellulose and is more resistant to oxidation than regenerated cellulose. The invention proceeds by crosslinking dissolved cellulose and forming a film from  
15 this crosslinked cellulose.

Cellulose, with a degree of polymerization from 200 to 1200, in the form of, but not limited to, microcrystalline cellulose, cotton fiber, paper and microgranular cellulose, is dissolved using a variety of different solvents,  
20 including, but not limited to, LiCl/DMAC, trifluoroacetic acid and N-morpholine N-oxide. With LiCl/DMAC, the preferred range is 3 to 8% wt LiCl to DMAC and the applicable range for the percent weight solution of cellulose to solvent is 1 to 11%.

25 After dissolving the cellulose, the hydroxyl groups on the cellulose are deprotonated by adding an amount of a base, in particular an inorganic hydroxide such as NaOH. The base is added in sufficient quantity to deprotonate just a small fraction of available hydroxyls, usually 1 to  
30 10%, for an excess would result in side reactions causing chain cleavage with consequent depolymerization and degradation in film strength.

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After the deprotonation is complete, a dihalide containing 4 to 16 carbon atoms is introduced into the reaction vessel. The dihalide reacts with deprotonated sites on adjacent cellulose chains to form hydrocarbon cross-link groups. The crosslink reaction preferably conducted at temperatures from 55 to 90 degrees Celsius for periods ranging from 8 to 24 hours. The amount of dihalide added is the gram-equivalent to all of the hydroxyls available. The NaOH is allowed to settle and the solution is then cast via conventional methods. These methods are known to those skilled in the art of membrane fabrication. They include extrusion of the solution onto a conveyor belt, casting onto a glass plate with a casting knife or casting onto a well-leveled glass plate to form a separator having a thickness from 10 microns to 250 microns.

After casting, the resulting solution is coagulated with conventional techniques, preferably using water as the coagulating agent. Coagulation may be attained either by exposure to ambient moisture or by direct application of a water stream to the resulting solution. The coagulated cellulose material is washed to remove the solvent and the salt. It is possible to employ alcohols mixed with water, but it is preferable that they be kept below 50% by volume.

After thorough washing of the resulting gel, the gel may be dried with any conventional technique such as air drying, vacuum drying or press drying.

#### Example 1

100 g of LiCl is dissolved in 2 kg of dimethylacetamide (DMAC) at room temperature. 40 g of microcrystalline cellulose (MCC, Aldrich 31,069-7) is placed in a solution containing 2.1 kg of LiCl/DMAC solvent and heated to 120 degrees Celsius for 15 minutes. The

cooled solution is clear. 16 grams of NaOH is added to this solution and the solution is brought to 90 degrees Celsius for 3 hours. The solution is allowed to cool to 70 degrees Celsius at which point 63 g of 1,6-diiodohexane is added for 16 hours.

The solution is cooled to room temperature and cast on a glass-tray. After gelling with ambient moisture the gel is rinsed with deionized water to remove all solvent. The clean gel is placed in a dry-press mount at 105 degrees Celsius for 1.5 hours at which point a clear film is obtained.

Different cellulose were subjected to crosslinking as described in Example 1. The dried films were then subjected to a strength test as follows. A one inch squared piece of film is first soaked for 2 minutes in an aqueous solution comprising 50% by weight potassium hydroxide. It is clamped between two flat surfaces having openings slightly smaller than the film area. Next the film is stressed using a penetrometer with a spherical Teflon ball of  $\frac{1}{2}$  inch diameter at the tip. The weight to rupture is noted. Table 1 shows rupture weight in Newtons. Reported results are averages of several readings. The as cast data refer to celluloses of different degree of polymerization obtained from several vendors:

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Table 1

Film	As Cast	Crosslinked
Cellulose A	2.5	3.0
Cellulose B	2.4	3.8
Cellulose C	5.1	6.7
Cellulose D	7.5	8.3
Cellulose E	7.1	9.1
Cellulose F	0.8	1.5

Cellulose G	2.7	3.3
Cellulose H	3.2	4.1
Cellulose I	3.5	3.5

Samples from the same films as above were placed in a bath of 50% KOH at 50 degrees Celsius for two weeks. Table 2 below reports rupture weights in Newtons for these films

Table 2

	Film	As Cast	Crosslinked
	Cellulose A	0.55	0.58
10	Cellulose B	0.20	0.60
	Cellulose C	0.40	0.80
	Cellulose D	0.30	0.90
	Cellulose E	0.60	0.70
	Cellulose F	0.00	0.20
15	Cellulose G	0.25	0.80
	Cellulose H	0.50	0.60
	Cellulose I	0.15	0.45

## Example 2

Example 1 was repeated, except that 40g 1,10-diiododecane is added as the crosslinking agent.

## Example 3

20 g of powdered cellulose (International Filler Corporation) is dissolved in 2 kg of 5% LiCl/DMAC and heated to 130 degrees Celsius for 1 hour. The solution is cooled and 18g of NaOH and 36 g 1,6-diiodohexane are added simultaneously and brought to the indicated temperature for a certain amount of time. The film is gelled, rinsed and dried as outlined in Example 1.

Experiments conducted using the crosslinked cellulose as described above in the separators of zinc alkaline batteries have indicated a measurable increase in mechanical strength.

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